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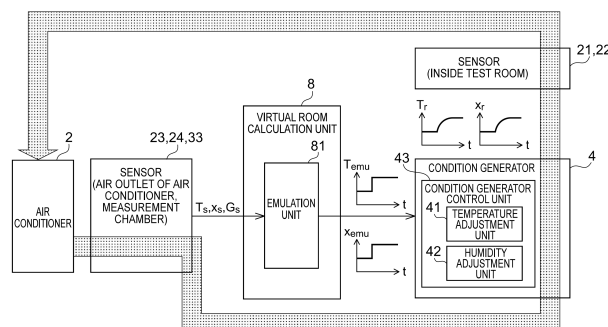
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(54) **PERFORMANCE MEASUREMENT METHOD FOR AIR CONDITIONER, PERFORMANCE MEASUREMENT DEVICE FOR AIR CONDITIONER, AND CONTROL METHOD FOR CONDITION GENERATOR**

(57) The invention provides a method for measuring the performance of an air conditioner that achieves an improvement in the accuracy of performance measurement of a dynamically controlled air conditioner. A method for measuring the performance of an air conditioner 2 comprises: emulating the air state of a virtual room, the virtual room being a virtual reproduction of an actual room, using the air state of the air blown out from the air conditioner 2 to determine future changes in the air state of the virtual room; compensating for a delay in the

air state of the test room relative to a setting of the condition generator 4 in the case of using the future change in the air state of the virtual room for the setting of the condition generator; controlling the condition generator 4 using, as the setting, the future change in the air state of the virtual room for which the delay has been compensated; and measuring the performance of the air conditioner in the test room under the measurement conditions generated by the condition generator 4.

FIG. 3



Description

TECHNICAL FIELD

[0001] The present invention relates to a method and apparatus for measuring the performance of an air conditioner, and a method for controlling a condition generator.

BACKGROUND ART

[0002] As a simple method for measuring the performance of an air conditioner, a method is known in which the performance is measured by driving the air conditioner in a stable condition without performing capacity control by fixing the rotation speed of the compressor. However, since such performance measurement in a fixed operating state, that is, a static operating state is not carried out under actual operating conditions, there is a risk that a discrepancy may arise between the measurement results and the performance in the actual use environment.

[0003] Therefore, performance measurement while dynamically changing the operating state of the air conditioner has been studied. Such performance measurement under a dynamic operating state is also sometimes referred to as load-based performance measurement. According to the technology disclosed in Patent Literature 1, a predetermined test environment, such as a test room, is prepared to measure the performance of an air conditioner in a dynamic operating state. This technology involves measuring the performance of an air conditioner in a dynamic operating state after controlling electrical equipment, human body models, and the like placed in the test room in consideration of the actual use environment, such as heat generation from the electrical equipment, living heat inside the room and the like.

LIST OF CITATIONS

Patent Literature

[0004] [Patent Literature 1] JP 2007-333557 A

SUMMARY OF INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0005] The technology disclosed in Patent Literature 1 requires the construction of identical test rooms at each location to ensure identical implementation environments when the performance measurement is implemented at different sites. However, it is difficult to reproduce a completely identical test environment, including the external environment, which may lead to variations in the performance measurement results.

[0006] Therefore, a method has been studied in which a condition generator configured by an air conditioner

different from the air conditioner to be measured, is installed in the test room. This method emulates a virtual test room (virtual room) based on the state of the air blown out from the air conditioner to be measured, followed by the performance measurement of the air conditioner to be measured while controlling the condition generator so that the actual air state of the test room matches the air state of the virtual room derived from the emulation. This method can exclude factors that depend on the environment such as the heat capacity of the test room and thus can measure the performance of the air conditioner in a dynamic operating state while achieving a highly reproducible measurement environment.

[0007] However, even with this method involving emulation, delays may occur due to the control of the condition generator and elements such as the thermal capacity of the air in the test room, which may cause the change (response) of the actual test room state to lag behind the virtual room state derived from the emulation. As a result, there has been a problem that these delays can affect the results of air conditioner performance measurement under dynamic operating conditions.

[0008] The present invention has been made in view of the above-described problem, and an object thereof is to provide a method and apparatus for measuring the performance of an air conditioner and a method for controlling a condition generator, which achieves an improvement in the accuracy of performance measurement of the air conditioner in a dynamic operating state.

MEANS TO SOLVE THE PROBLEM

[0009] The method for measuring the performance of an air conditioner according to the present invention measures the performance of an air conditioner dynamically operated in a test room equipped with a condition generator that generates measurement conditions. This method for measuring the performance of an air conditioner comprises: emulating the air state of a virtual room, the virtual room being a virtual reproduction of an actual room, using the air state of the air blown out from the air conditioner to determine future changes in the air state of the virtual room; compensating for a delay in the air state of the test room relative to a setting of the condition generator in the case of using the future change in the air state of the virtual room for the setting of the condition generator; controlling the condition generator using, as the setting, the future change in the air state of the virtual room for which the delay has been compensated; and measuring the performance of the air conditioner in the test room under the measurement conditions generated by the condition generator.

[0010] The apparatus for measuring the performance of an air conditioner according to the present invention measures the performance of an air conditioner dynamically operated in a test room equipped with a condition generator that generates measurement conditions. The apparatus for measuring the performance of an air con-

ditioner comprises: an emulation unit configured to emulate the air state of a virtual room, the virtual room being a virtual reproduction of an actual room, using the air state of the air blown out from the air conditioner to determine future changes in the air state of the virtual room; a delay compensation unit configured to compensate for a delay in the air state of the test room relative to a setting of the condition generator in the case of using the future change in the air state of the virtual room for the setting of the condition generator and to control the condition generator using, as the setting, the future change in the air state of the virtual room for which the delay has been compensated; and an air conditioning performance measurement unit configured to measure the performance of the air conditioner in the test room under the measurement conditions generated by the condition generator.

[0011] The method for controlling a condition generator according to the present invention controls a condition generator that is installed in a test room and generates conditions for performance measurement of an air conditioner dynamically operated. This method for controlling a condition generator comprises: emulating the air state of a virtual room, the virtual room being a virtual reproduction of an actual room, using the air state of the air blown out from the air conditioner to determine future changes in the air state of the virtual room; compensating for a delay in the air state of the test room relative to a setting of the condition generator in the case of using the future change in the air state of the virtual room for the setting of the condition generator; and controlling the condition generator using, as the setting, the future change in the air state of the virtual room for which the delay has been compensated.

EFFECT OF THE INVENTION

[0012] The method and apparatus for measuring the performance of an air conditioner and the method for controlling a condition generator of the present invention compensate for a delay in the change of the air state of the test room relative to the set value input to the condition generator with respect to the air state of the virtual room derived from emulation. This delay compensation reduces the difference between the air state of the test room and that of the virtual room when measuring the performance of a dynamically controlled air conditioner thereby improving the accuracy of the performance measurement.

BRIEF EXPLANATION OF FIGURES

[0013]

[FIG. 1] FIG. 1 is a schematic configuration diagram of a test room for measuring the performance of an air conditioner, common to each embodiment.

[FIG. 2] FIG. 2 is an explanatory diagram of the operation of the virtual room calculation unit of the

first embodiment.

[FIG. 3] FIG. 3 is an explanatory diagram of the operation of a virtual room calculation unit of a comparative example.

[FIG. 4] FIG. 4 is a graph showing the performance of the delay model generated in the first example.

[FIG. 5] FIG. 5 is a graph showing the performance of the generated compensation model.

[FIG. 6] FIG. 6 is a graph showing the performance of the compensation model generated in the second example.

[FIG. 7] FIG. 7 is a graph showing measurement results when actually operated in the test room using the generated delay model.

[FIG. 8] FIG. 8 is an explanatory diagram of the operation of the virtual room calculation unit of the second embodiment.

EMBODIMENTS

[0014] Embodiments of the present invention will be described in detail below with reference to the drawings. In the following description, the same constituent elements are denoted by the same reference numerals, and redundant explanations are omitted.

(First Embodiment)

[0015] FIG. 1 is a schematic configuration diagram of a test room 1. The illustrated test room 1 has a configuration common to each embodiment. As illustrated, the test room 1 is provided with: an air conditioner 2 to be measured, a measuring chamber 3 that captures the air blown out from the air conditioner 2, and a condition generator 4 that takes in the air blown out from the measuring chamber 3 and generates the conditions for performance measurement by setting the air state (temperature and humidity) inside the test room 1 to a predetermined air state. As an example, the condition generator 4 is an air conditioner different from the air conditioner 2 and is capable of controlling temperature and humidity. The air conditioner 2 operates integrally with an outdoor unit 5, and the condition generator 4 operates integrally with an outdoor unit 6.

[0016] The air blown out from the air conditioner 2 blows into the measuring chamber 3. Furthermore, part of the air blown out from the measuring chamber 3 blows into the condition generator 4 while the rest blows into the test room 1. Alternatively, all of the air blown out from the measuring chamber 3 may blow into the condition generator 4. The temperature and humidity of the air blown into the condition generator 4 are changed by the condition generator 4.

[0017] Two control units, an air conditioning performance measurement unit 7 for executing performance measurement for the air conditioner 2, and a virtual room calculation unit 8 for determining a target value for the condition generator 4 are provided integrally in a perfor-

mance measurement apparatus 9. The performance measurement apparatus 9 is composed of a calculator (computer) equipped with a central processing unit (CPU), a memory unit, and the like. The performance measurement apparatus 9 executes processing to realize the functions of the air conditioning performance measurement unit 7 and the virtual room calculation unit 8 by executing a specific program stored in the memory unit. Note that the air conditioning performance measurement unit 7 and the virtual room calculation unit 8 may be configured by a single calculator or by a plurality of calculators.

[0018] The air conditioning performance measurement unit 7 is configured to calculate the air conditioning performance of the air conditioner 2 from the measured air state inside the test room 1 and the power consumption of the air conditioner 2. Since the air conditioner 2 is dynamically controlled according to the measurement conditions, the air conditioning performance measurement unit 7 can execute dynamic performance measurement of the air conditioner 2.

[0019] The virtual room calculation unit 8 predicts the air state (temperature, humidity) of a room virtually created (hereinafter referred to as "virtual room") by emulation using the measured air state of the air blown out from the air conditioner 2 and controls the condition generator 4 so that the air state of the test room 1 matches the air state of the virtual room. The use of the condition generator 4 to make the air state of the test room 1 match the air state of the virtual room as described can suppress variations in the results of air conditioning performance measurement caused by differences in the configuration of a plurality of test rooms 1 installed in different locations.

[0020] The test room 1 is entirely covered by a heat insulation material 10. The test room 1 has a double-layer structure in which an inner ceiling 12 is provided inside an outer wall 11 of the ceiling and is configured to allow the air blown out from the condition generator 4 to be taken in between the outer wall 11 and the inner ceiling 12. The inner ceiling 12 is provided with a plurality of holes, and the air blown out from the condition generator 4 is diffused throughout the inside of the test room 1 via these holes. Note that, although the inner ceiling 12 is provided inside the test room 1 in the present embodiment, the inner ceiling 12 may not be provided, and the air blown out from the condition generator 4 may be blown directly or indirectly into the test room 1.

[0021] The air conditioner 2 is connected via piping or the like to the outdoor unit 5 installed outside the test room 1. The outdoor unit 5 is equipped with a compressor or the like, and the air conditioner 2 and the outdoor unit 5 operate as an integral unit so that air at a predetermined temperature, humidity, and airflow rate is allowed to be blown out from the air conditioner 2.

[0022] A thermometer 21 for measuring the room temperature T_r inside the test room 1, and a wet-bulb thermometer 22 for measuring humidity are installed in the vicinity of the air intake port of the air conditioner 2. The

room humidity x_r is determined using the wet-bulb temperature measured by the wet-bulb thermometer 22 and the room temperature T_r measured by the thermometer 21. A thermometer 23 for measuring the blowing temperature T_s of the air blown out from the air conditioner 2, and a hygrometer 24 for directly measuring humidity are also installed in the vicinity of the air outlet port of the air conditioner 2. Since a temperature and humidity distribution exists at the air outlet port of the air conditioner 2, it is preferable that the hygrometer 24 is installed to directly measure the humidity x_s of the blowing air, in place of a wet-bulb thermometer that measures humidity by comparing with the temperature measured by a thermometer.

[0023] Furthermore, the air conditioner 2 is controlled integrally with the outdoor unit 5, and the power consumption P used for air conditioning of the test room 1 is determined using a power meter 25 provided in the air conditioner 2 and a power meter 53 provided in the outdoor unit 5. A thermometer 51 and a wet-bulb thermometer 52 are provided in the vicinity of the outdoor unit 5, which respectively measure the outdoor temperature T_o and the outdoor humidity x_o outside the test room 1. The outdoor temperature T_o and the outdoor humidity x_o are not used in the first embodiment but are used in the second embodiment. Note that a configuration could be used in which a power meter is provided on either the air conditioner 2 or the outdoor unit 5.

[0024] A thermometer 31 and a wet-bulb thermometer 32 are provided inside the measuring chamber 3. An air flow meter 33 is provided at the outlet of the measuring chamber 3. The air flow meter 33 determines the differential pressure between two pressure gauges provided along the air flow and calculates the air volume G_s blown out from the air conditioner 2 based on the differential pressure.

[0025] Here, since a temperature and humidity distribution exists in the vicinity of the air outlet port of the air conditioner 2, errors may occur in the temperature T_s and humidity x_s acquired using the thermometer 23 and the hygrometer 24. In contrast, the temperature T_s' and humidity x_s' determined by the thermometer 31 and the wet-bulb thermometer 32 may have errors relative to the actual state of the air blown out from the air conditioner 2, when compared to the blowing temperature T_s and blowing humidity x_s measured by the thermometer 23 and the hygrometer 24 provided near the air outlet of the air conditioner 2. This is because the measuring chamber 3 is located at a distance from the air outlet of the air conditioner 2, and the measuring chamber 3 itself has heat capacity. However, since the blowing air is agitated within the measuring chamber 3, a more stable blowing air state measurement can be achieved.

[0026] Therefore, the measurement accuracy of the blowing temperature T_s and the blowing humidity x_s can be enhanced by calibrating the blowing temperature T_s and the blowing humidity x_s measured by the thermometer 23 and the hygrometer 24, using the temperature T_s' and the humidity x_s' determined by the thermometer

31 and the wet-bulb thermometer 32 in a steady state in advance. Furthermore, in cases where the measurement delay resulting from the distance between the air outlet port of the air conditioner 2 and the measuring chamber 3 can be regarded as relatively small, the blowing temperature T_s and blowing humidity x_s from the air conditioner 2 may be determined by measuring the air state of the measuring chamber 3 using the thermometer 31 and the wet-bulb thermometer 32, without using the thermometer 23 and the hygrometer 24.

[0027] The air conditioning performance measurement unit 7 receives inputs of: the room temperature T_r and the room humidity x_r acquired using the thermometer 21 and the wet-bulb thermometer 22, respectively; the blowing temperature T_s , the blowing humidity x_s (which may be calibrated by the temperature T_s and the humidity x_s acquired by the thermometer 31 and the wet-bulb thermometer 32), and the blowing air volume G_s , acquired using the thermometer 23, the hygrometer 24, and the air flow meter 33, respectively; and the power consumption P measured by the power meters 25, 53.

[0028] The air conditioning performance measurement unit 7 calculates the enthalpy of the room air from the room temperature T_r and the room humidity x_r , calculates the enthalpy of the air blown out from the air conditioner 2 using the blowing temperature T_s and the blowing humidity x_s , and calculates the difference between the two enthalpies. Then, the air conditioning performance measurement unit 7 determines the air conditioning capacity (cooling capacity/heating capacity) by multiplying the enthalpy difference by the blowing air volume G_s . Finally, the air conditioning performance measurement unit 7 calculates the air conditioning performances of the air conditioner 2 and the outdoor unit 5 by dividing the determined air conditioning capacity by the power consumption P .

[0029] The virtual room calculation unit 8 receives inputs of the blowing temperature T_s , the blowing humidity x_s , and the blowing air volume G_s acquired using the thermometer 23, the hygrometer 24, and the air flow meter 33, and uses these inputs to emulate the air state of the virtual room. Then, the virtual room calculation unit 8 transmits set values (set temperature T_{set} , set humidity x_{set}) to the condition generator 4, such that the air state of the test room 1 matches the air state of the virtual room derived from the emulation. This enables measurement of the air conditioning performance of the air conditioner 2 in the test room 1, where the air condition matches that of the virtual room.

[0030] The condition generator 4 is configured by an air conditioner different from the air conditioner 2 to be measured and operates integrally with the outdoor unit 6 connected via piping or the like. The condition generator 4 takes in part or all of the air blown out from the measuring chamber 3 and operates according to the set temperature T_{set} and set humidity x_{set} from the virtual room calculation unit 8.

[0031] Additionally, thermometers, hygrometers, and

wet-bulb thermometers other than the thermometers 21, 23, and 51, the hygrometer 24, and the wet-bulb thermometers 22 and 52 may be provided inside and outside the test room 1. The use of the measurement results from a plurality of thermometers, hygrometers, and wet-bulb thermometers can determine the room temperature T_r and room humidity x_r , the blowing temperature T_s and blowing humidity x_s , and the outdoor temperature T_o and outdoor humidity x_o with higher accuracy.

[0032] FIG. 2 is an explanatory diagram of the operation of a virtual room calculation unit 8 of the present embodiment. This figure indicates the flow of control by thin arrows, and the flow of air by thick arrows (with dotted hatching).

[0033] As indicated by the thick arrows, the air blown out from the air conditioner 2 passes through the measuring chamber 3, and after being modified to predetermined conditions (temperature, humidity) by the condition generator 4, is returned into the test room 1 again, and is sucked into the air conditioner 2.

[0034] Meanwhile, as indicated by the thin arrows, the blowing temperature T_s , blowing humidity x_s , and blowing airflow rate G_s measured by sensors (thermometer 23, hygrometer 24, and air flow meter 33) provided at the outlet port of the air conditioner 2 and in the measuring chamber 3 are input to the virtual room calculation unit 8. The virtual room calculation unit 8 comprises an emulation unit 81 and a delay compensation unit 82. Note that in the present embodiment, an example has been described in which the emulation unit 81 and the delay compensation unit 82 integrally constitute the virtual room calculation unit 8, but the emulation unit 81 and the delay compensation unit 82 may be independent and different computers or software.

[0035] The emulation unit 81 receives the measured blowing temperature T_s , blowing humidity x_s , and blowing airflow rate G_s , and emulates the air state of the virtual room to determine a virtual room temperature T_{emu} and a virtual room humidity x_{emu} . This emulation reproduces the amount of heat into and out of the virtual room, specifically incident solar radiation, the state of ventilation with the exterior (including drafts), and living heat generated by occupants and electrical appliances inside.

[0036] More specifically, the emulation unit 81 uses the various parameters of the state of the air blown out from the air conditioner 2, that is, the blowing temperature T_s , the blowing humidity x_s , and the blowing air volume G_s , to solve differential equations in consideration of the heat transfer into and out of the virtual room and predict the temporal change in the air state (temperature, humidity) of the virtual room. These future predicted values of the air state in the virtual room are used to control the condition generator 4 after being corrected by the subsequent delay compensation unit 82. These future predicted values of the air state in the virtual room indicate the air state that changes over time and are denoted by the virtual room temperature T_{emu} and the virtual room humidity x_{emu} .

[0037] The delay compensation unit 82 receives the blowing temperature T_s , the blowing humidity x_s , and the blowing air volume G_s measured by the sensors, similar to the emulation unit 81, in addition to the virtual room temperature T_{emu} and the virtual room humidity x_{emu} output from the emulation unit 81.

[0038] Whereupon, due to the mechanical control of the condition generator 4 and the thermal capacity, etc., of the air within the test room 1, the change (response) of the air state (room temperature T_r , room humidity x_r) within the test room 1 is delayed relative to the settings (set temperature T_{set} , set humidity x_{set}) input to the condition generator 4.

[0039] Therefore, the delay compensation unit 82 performs a correction so as to compensate for the delay with respect to the virtual room temperature T_{emu} and the virtual room humidity x_{emu} output from the emulation unit 81, by feedforward control using the input blowing temperature T_s , blowing humidity x_s , and blowing air volume G_s . The delay compensation unit 82 outputs the set temperature T_{set} and the set humidity x_{set} , for which the delay has been compensated, to the condition generator 4, and the condition generator 4 is controlled accordingly.

[0040] Furthermore, since the control target of the condition generator 4 is the air state of the test room 1 and thus uncertainty exists in the control, a control error may arise in the air state. For this reason, the delay compensation unit 82 may also be configured to compensate for such errors.

[0041] The condition generator 4 has a temperature adjustment unit 41 and a humidity adjustment unit 42 and operates based on the set temperature T_{set} and the set humidity x_{set} output from the delay compensation unit 82. The condition generator 4 operating in this way can allow the room temperature T_r and the room humidity x_r of the test room 1 to be brought closer to the virtual room temperature T_{emu} and the virtual room humidity x_{emu} . Note that the temperature adjustment unit 41 and the humidity adjustment unit 42 are control units of the condition generator 4 and may be configured integrally as a condition generator control unit 43.

[0042] FIG. 3 is an explanatory diagram of the operation of a virtual room calculation unit 8 of a comparative example. The configuration illustrated in this figure is different from the virtual room calculation unit 8 of the first embodiment illustrated in FIG. 2 in that the delay compensation unit 82 within the virtual room calculation unit 8 is omitted.

[0043] Since the delay compensation unit 82 is omitted, the condition generator 4 is controlled using the state of the virtual room (virtual room temperature T_{emu} , virtual room humidity x_{emu}) determined by the emulation unit 81 as the set value. Such control causes delays occurring due to the mechanical control of the condition generator 4, the heat capacity of the air inside the test room 1, and the like, and therefore the state (room temperature T_r , room humidity x_r) inside the test room 1 is

delayed relative to the set values.

[0044] Therefore, in the present embodiment, a delay compensation unit 82 provided downstream of the emulation unit 81 as illustrated in FIG. 2 enables the set temperature T_{set} and set humidity x_{set} , for which delays have been compensated, to be used for controlling the condition generator 4. As a result, the air state of the test room 1 (room temperature T_r , room humidity x_r) can be brought close to the air state of the virtual room (virtual room temperature T_{emu} , virtual room humidity x_{emu}) determined by the emulation unit 81.

[0045] The delay compensation unit 82 may be configured, for example, by the following method. First of all, after generating a delay model that indicates the delay of the air state of the test room 1 relative to the set values of the condition generator 4, a compensation model that compensates for that delay is generated. Then, the delay compensation unit 82 is configured using the compensation model thus generated.

[0046] In detail, first of all, a delay model is generated which models the delay that occurs in a case where the delay compensation unit 82 does not exist, such as in the comparative example of FIG. 3. For example, the delay model is configured by machine learning using: past data of the settings (set temperature T_{set} , set humidity x_{set}) of the condition generator 4; past data of the air state (virtual room temperature T_{emu} , virtual room humidity x_{emu}) of the virtual room; past data of the air state (room temperature T_r , room humidity x_r) of the test room 1; and past data of the air state (blowing temperature T_s , blowing humidity x_s , blowing air volume G_s) of the air blown out from the air conditioner 2, and the like.

[0047] Next, a compensation model that compensates for the delay is generated using the generated delay model. For example, when one of the inputs to the delay model is changed, the output value changes according to the change in the input. One of the changing output values is the air state of the test room 1. Therefore, a change in the input is determined such that the deviation of the air state of the test room 1 after the change with respect to the air state of the virtual room is minimized over time. For example, the use of a genetic algorithm allows such input changes to be repeated to determine the optimal change. Finally, a compensation model that compensates for the determined change can be generated.

[0048] In this way, the delay model is generated, and thereafter, the compensation model is generated, and the delay compensation unit 82 can be configured using the generated delay model. Note that, although in the above description, machine learning was used to generate the delay model and the compensation model, the present invention is not limited to machine learning, and a mathematical model that describes the phenomena within the condition generator 4 may also be used.

[0049] Hereinafter, two specific examples of simulations for the case of configuring the delay compensation unit 82 by machine learning will be described. The first

example is illustrated in FIGS. 4 and 5, and involves machine learning using past measurement data, and the performance of the compensation model is verified by simulation. The second example is illustrated in FIGS. 6 and 7 and involves machine learning using explicitly the error of the indoor state of the test room 1 from the air state of the virtual room as a parameter, and the performance of the compensation model is verified by actual measurement. In common to the both examples, the simulations are performed only for temperature but not for humidity.

[0050] In the first example, past measurement data was used to generate a delay model indicating the delay of the room temperature T_r with respect to the virtual room temperature T_{emu} , which is the setting of the condition generator 4. Thereafter, the set temperature T_{set} of the condition generator 4 is changed to determine such a set temperature T_{set}' that the difference ($T_r' - T_{emu}$) between the room temperature T_r' resulting from the changed set temperature T_{set}' and the virtual room temperature T_{emu} of the emulation result becomes minimal (smaller, or a predetermined value or less). As a result, a delay model is generated in which the virtual room temperature T_{emu} is an input and the set temperature T_{set}' is an output.

[0051] FIG. 4 is a graph showing the validity of a delay model derived from the machine learning in the first example. In this figure, the vertical axis indicates temperature normalized to a number between -1 and +1, and the horizontal axis indicates time in seconds. Furthermore, the dashed-dotted line indicates a virtual room temperature T_{emu} determined by the emulation unit 81 while the solid line indicates a room temperature T_r within the test room 1 measured by the thermometer 21. The fine dotted line indicates a room temperature T_r' determined by compensating for the delay with respect to the virtual room temperature T_{emu} using the delay model. Note that in this figure, the portion surrounded by the dashed-double-dotted line rectangle in the upper part is enlarged and shown in the lower part.

[0052] As illustrated, the room temperature T_r' indicated by the fine dotted line substantially matches the room temperature T_r inside the test room 1 that has been measured. Since the both values match each other for most of the time, or the difference therebetween is less than or equal to a predetermined value, it can be understood that the delay model has been correctly configured.

[0053] FIG. 5 is a graph illustrating the performance of a compensation model generated through machine learning. In this figure, the portion surrounded by the dashed-double-dotted line rectangle in the upper part is enlarged and shown in the lower part.

[0054] Similarly to FIG. 4, this figure indicates the virtual room temperature T_{emu} by a dashed-dotted line. For comparison with FIG. 4, the room temperature T_r is indicated by a solid line. Furthermore, the thin solid line indicates the setting (set temperature T_{set}') for the condition generator 4, for which the delay has been compensated with respect to the virtual room temperature T_{emu}

using the compensation model. The thin dotted line indicates the temperature of the test room 1 (room temperature T_r') generated by simulation using the delay model with this set temperature T_{set}' as an input. Note that there are many overlapping portions between the dashed-dotted line (virtual room temperature T_{emu}) and the fine dotted line (room temperature T_r'), and among the small "dots" constituting the fine dotted line, the portions overlapping with the dashed-dotted line are indicated in white.

[0055] As illustrated in this figure, the set temperature T_{set}' is generated with respect to the virtual room temperature T_{emu} using the compensation model. Then, the result, for the case of using this set temperature T_{set}' for controlling the condition generator 4 can be derived as a simulation result from the delay model, and the room temperature T_r' as indicated by the thin dotted line is determined.

[0056] Since the virtual room temperature T_{emu} (indicated by the dashed-dotted line) matches the room temperature T_r' (indicated by the fine dotted line) determined using the delay model over much of the time, it can be understood that a compensation model capable of correctly compensating for the delay has been configured.

Then, the delay compensation unit 82 configured using this compensation model can suppress the delay of the room temperature T_r with respect to the virtual room temperature T_{emu} and thus can improve the accuracy of the performance measurement of the air conditioner 2 using the virtual room.

[0057] In the second example, a delay model is generated by machine learning using explicitly the error of the room state of the test room 1 from the air state of the virtual room as a parameter. That is, the compensation model generated based on this delay model can directly compensate for not only the delay but also the error.

[0058] FIG. 6 is a graph illustrating the performance of the compensation model generated via machine learning in the second example. This figure, compared to the examples of FIGS. 4 and 5, indicates the temperature on the vertical axis without being normalized. The circles indicate the set values (set temperature T_{set}) for the condition generator 4 generated using the compensation model. The solid line indicates the room temperature T_r determined using the delay model based on these set values (set temperature T_{set}). The dashed line indicates the virtual room temperature T_{emu} .

[0059] As illustrated, the room temperature T_r indicated by the solid line substantially matches the virtual room temperature T_{emu} indicated by the dashed line. Since the both values match each other for much of the time, or the difference therebetween is less than a predetermined value, it can be understood that the delay model has been correctly configured.

[0060] FIG. 7 is a graph illustrating the measured temperature of the test room 1 in a case where the delay compensation unit 82 generated using the compensation model generated via machine learning was actually

used. The circles indicate the set values (set temperature T_{set}) for the condition generator 4 generated using the compensation model. The dashed line indicates the virtual room temperature T_{emu} . The triangles indicate the room temperature T_r measured inside the test room 1, which was controlled based on these set values (set temperature T_{set}).

[0061] In the second example as described above, the measured room temperature T_r indicated by the triangles substantially matches the virtual room temperature T_{emu} indicated by the dashed line. Since the both values match each other for much of the time, or the difference therebetween is less than a predetermined value, it can be understood that the delay has been compensated by the delay compensation unit 82.

[0062] According to the method for measuring performances of the air conditioner 2 of the first embodiment, a delay compensation unit 82 compensates for a delay in the change (response) of the air state of the test room 1 (room temperature T_r , room humidity x_r) relative to the set values (virtual room temperature T_{emu} , virtual room humidity x_{emu}) input to the condition generator 4, with respect to the air state of the virtual room (virtual room temperature T_{emu} , virtual room humidity x_{emu}) determined by the emulation unit 81. Such delay compensation can reduce the difference between the air state of the test room 1 (room temperature T_r , room humidity x_r) and the air state of the virtual room (virtual room temperature T_{emu} , virtual room humidity x_{emu}) and thus can improve the accuracy of the performance measurement of the air conditioner 2.

[0063] According to the method for measuring performances of the air conditioner 2 of the first embodiment, the delay compensation unit 82 is operated by feedforward control using the air state of the air blown out from the air conditioner 2 (blowing temperature T_s , blowing humidity x_s , blowing airflow rate G_s). Such feedforward control can improve the accuracy of the performance measurement of the air conditioner 2.

[0064] According to the method for measuring the performances of the air conditioner 2 of the first embodiment, the air state of the virtual room reproduced by the condition generator 4 includes a virtual room temperature T_{emu} and a virtual room humidity x_{emu} . Thus, reproduction of both the temperature and humidity of the virtual room in the test room 1 enhances the reproducibility of the measurement conditions for the air conditioner 2 and can improve the accuracy of the performance measurement for the air conditioner 2.

[0065] According to the method for measuring the performances of the air conditioner 2 of the first embodiment, a delay model is generated that indicates the delay of the change (response) of the air state (room temperature T_r , room humidity x_r) of the test room 1 relative to the state (virtual room temperature T_{emu} , virtual room humidity x_{emu}) of the virtual room, which becomes the set values for the condition generator 4. Then, by changing the state so that the delay becomes smaller, a setting for

the condition generator 4 after the change (virtual room temperature T_{emu} , virtual room humidity x_{emu}) is determined, and a compensation model used for compensating for the delay is generated based on the change. After the generation of the delay model, the compensation model is generated using the generated delay model thereby simplifying the method for configuring the models.

[0066] According to the method for measuring the performance of the air conditioner 2 of the first embodiment, compensation for the delay further compensates for an error in the air state of the test room 1 relative to the air state of the virtual room in a case where the delay has been compensated. Thus, by compensating not only for the delay but also for the error, the accuracy of the performance measurement of the air conditioner 2 can be improved.

(Second Embodiment)

[0067] In the first embodiment, the delay compensation unit 82 illustrated in Figure 2 compensates for the delay with respect to the air state of the virtual room (virtual room temperature T_{emu} , virtual room humidity x_{emu}) that becomes a set value for the condition generator 4 based on the air state in the measuring chamber 3 (blowing temperature T_s , blowing humidity x_s , blowing air volume G_s) using a delay model. In the second embodiment, an example of further using other parameters to improve the accuracy of delay compensation will be described.

[0068] FIG. 8 is an explanatory diagram of the operation of the virtual room calculation unit 8 of the second embodiment. Referring to this figure, input to the delay compensation unit 82 of the virtual room calculation unit 8 are: in addition to the air state (blowing temperature T_s , blowing humidity x_s , blowing air volume G_s) of the air blown out from the air conditioner 2, the air state (room temperature T_r , room humidity x_r) inside the test room 1 acquired by sensors (thermometer 21, wet-bulb thermometer 22) inside the test room 1, and the air state (outdoor temperature T_o , outdoor humidity x_o) outside the test room 1 acquired by sensors (thermometer 51, wet-bulb thermometer 52) outside the test room 1. The delay compensation unit 82 compensates for the delay with respect to the state (virtual room temperature T_{emu} , virtual room humidity x_{emu}) of the virtual room based on these inputs and uses what has been compensated as the set values (set temperature T_{set} , set humidity x_{set}) of the condition generator 4.

[0069] The delay in the response of the air state within the test room 1 relative to the set values input to the condition generator 4 may be considered to be caused by heat conduction/heat radiation from outside the test room 1 via the heat insulating material 10, in addition to delays caused by the control of the condition generator 4, the heat capacity of the air within the test room 1, and the like. In particular, since the outdoor unit 5 is increased in

temperature, a feedforward using the outdoor temperature T_o and outdoor humidity x_o measured by the thermometer 51 and wet-bulb thermometer 52 provided near the outdoor unit 5 is used to compensate for the delay due to the heat conduction/heat radiation from outside the test room 1.

[0070] Furthermore, the delay compensation unit 82 can directly determine the delay/advance of the response of the air state (room temperature T_r , room humidity x_r) inside the test room 1 with respect to the set values (set temperature T_{set} , set humidity x_{set}) of the condition generator 4 by accepting the air state (room temperature T_r , room humidity x_r) inside the test room 1.

[0071] Therefore, when the air state inside the test room 1 (room temperature T_r , room humidity x_r) is delayed with respect to the set values (set temperature T_{set} , set humidity x_{set}) of the condition generator 4, the level of compensation is further increased, and when the air state inside the test room 1 (room temperature T_r , room humidity x_r) is advanced with respect to the set values (set temperature T_{set} , set humidity x_{set}) of the condition generator 4, the level of compensation is decreased. In this manner, the delay compensation unit 82 can optimally compensate for the delay by feedback control using the air state inside the test room 1 (room temperature T_r , room humidity x_r).

[0072] In this embodiment, the delay compensation unit 82 compensates for the delay using the air state inside the test room 1 (room temperature T_r , room humidity x_r) and the air state outside the test room 1 (outdoor temperature T_o , outdoor humidity x_o) in addition to the air state inside the measuring chamber 3 (blowing temperature T_s , blowing humidity x_s , blowing air volume G_s). Even in such a case, machine learning can generate the delay model and the compensation model by increasing the number of the parameters handled during model generation.

[0073] According to the method for measuring the performance of the conditioner 2 of the second embodiment, the delay compensating unit 82 further compensates for the delay using feedback control based on the air state inside the test room 1 (room temperature T_r , room humidity x_r). Such feedback control can appropriately adjust the level of delay compensation, thereby further improving the accuracy of performance measurement for the air conditioner 2.

[0074] According to the method for measuring the performance of the conditioner 2 of the second embodiment, the delay compensating unit 82 further compensates for the delay using feedforward control based on the air state outside the test room 1 (outdoor temperature T_o , outdoor humidity x_o). Such feedforward control using the state of the air blown out from the air conditioner 2 (blowing air temperature T_s , blowing air humidity x_s , and blowing air volume G_s) can appropriately adjust the level of delay compensation, thereby further improving the accuracy of performance measurement for the air conditioner 2.

[0075] The present invention allows for various embodiments and modifications without departing from the broad spirit and scope of the present invention. Further, the embodiments described above are for explaining the present invention, and do not limit the scope of the present invention. That is, the scope of the present invention is indicated not by the embodiments but by the scope of claims. Various modifications made within the scope of claims and the scope of the significance of the invention equivalent thereto are regarded as being within the scope of the present invention.

Reference Signs List

[0076]

1	Test room
2	Air conditioner
3	Measuring chamber
4	Condition generator
5, 6	Outdoor unit
7	Air conditioning performance measurement unit
8	Virtual room calculation unit
9	Performance measurement apparatus
21, 23, 31, 51	Thermometer
24	Hygrometer
22, 32, 52	Wet-bulb thermometer
25, 53	Power meter
33	Air flow meter
81	Emulation unit
82	Delay compensation unit

Claims

1. A method for measuring the performance of an air conditioner, the air conditioner being dynamically operated in a test room equipped with a condition generator that generates measurement conditions, the method comprising:

emulating the air state of a virtual room, the virtual room being a virtual reproduction of an actual room, using the air state of the air blown out from the air conditioner to determine future changes in the air state of the virtual room;
 compensating for a delay in the air state of the test room relative to a setting of the condition generator in the case of using the future change in the air state of the virtual room for the setting of the condition generator;
 controlling the condition generator using, as the setting, the future change in the air state of the virtual room for which the delay has been compensated; and
 measuring the performance of the air conditioner in the test room under the measurement conditions generated by the condition genera-

tor.

2. The method for measuring the performance of an air conditioner according to claim 1, wherein the delay is compensated by feedforward control using the air state of the air blown out from the air conditioner. 5
3. The method for measuring the performance of an air conditioner according to claim 2, wherein the delay is further compensated by feedback control using the air state inside the test room. 10
4. The method for measuring the performance of an air conditioner according to claim 2 or 3, wherein the delay is further compensated by feedforward control using the air state outside the test room. 15
5. The method for measuring the performance of an air conditioner according to claim 1, wherein the air state comprises at least either one of the temperature or humidity of the air. 20
6. The method for measuring the performance of an air conditioner according to claim 1, wherein in the compensation for the delay, an error of the air state of the test room relative to the air state of the virtual room for which the delay has been compensated is further compensated for. 25
7. The method for measuring the performance of an air conditioner according to claim 1, comprising: 30
 - generating a delay model that indicates the delay of the air state of the test room relative to the setting of the condition generator; and 35
 - changing the setting for the condition generator so that the delay becomes smaller, and generating a compensation model used for the compensation of the delay based on said change. 40
8. An apparatus for measuring the performance of an air conditioner, the air conditioner being dynamically operated in a test room equipped with a condition generator that generates measurement conditions, the apparatus comprising: 45
 - an emulation unit configured to emulate the air state of a virtual room, the virtual room being a virtual reproduction of an actual room, using the air state of the air blown out from the air conditioner to determine future changes in the air state of the virtual room; 50
 - a delay compensation unit configured to compensate for a delay in the air state of the test room relative to a setting of the condition generator in the case of using the future change in the air state of the virtual room for the setting of the condition generator and to control the con- 55

dition generator using, as the setting, the future change in the air state of the virtual room for which the delay has been compensated; and an air conditioning performance measurement unit configured to measure the performance of the air conditioner in the test room under the measurement conditions generated by the condition generator.

9. A method for controlling a condition generator, the condition generator being installed in a test room and generating conditions for performance measurement of an air conditioner dynamically operated, the method comprising:

emulating the air state of a virtual room, the virtual room being a virtual reproduction of an actual room, using the air state of the air blown out from the air conditioner to determine future changes in the air state of the virtual room; compensating for a delay in the air state of the test room relative to a setting of the condition generator in the case of using the future change in the air state of the virtual room for the setting of the condition generator; and controlling the condition generator using, as the setting, the future change in the air state of the virtual room for which the delay has been compensated.

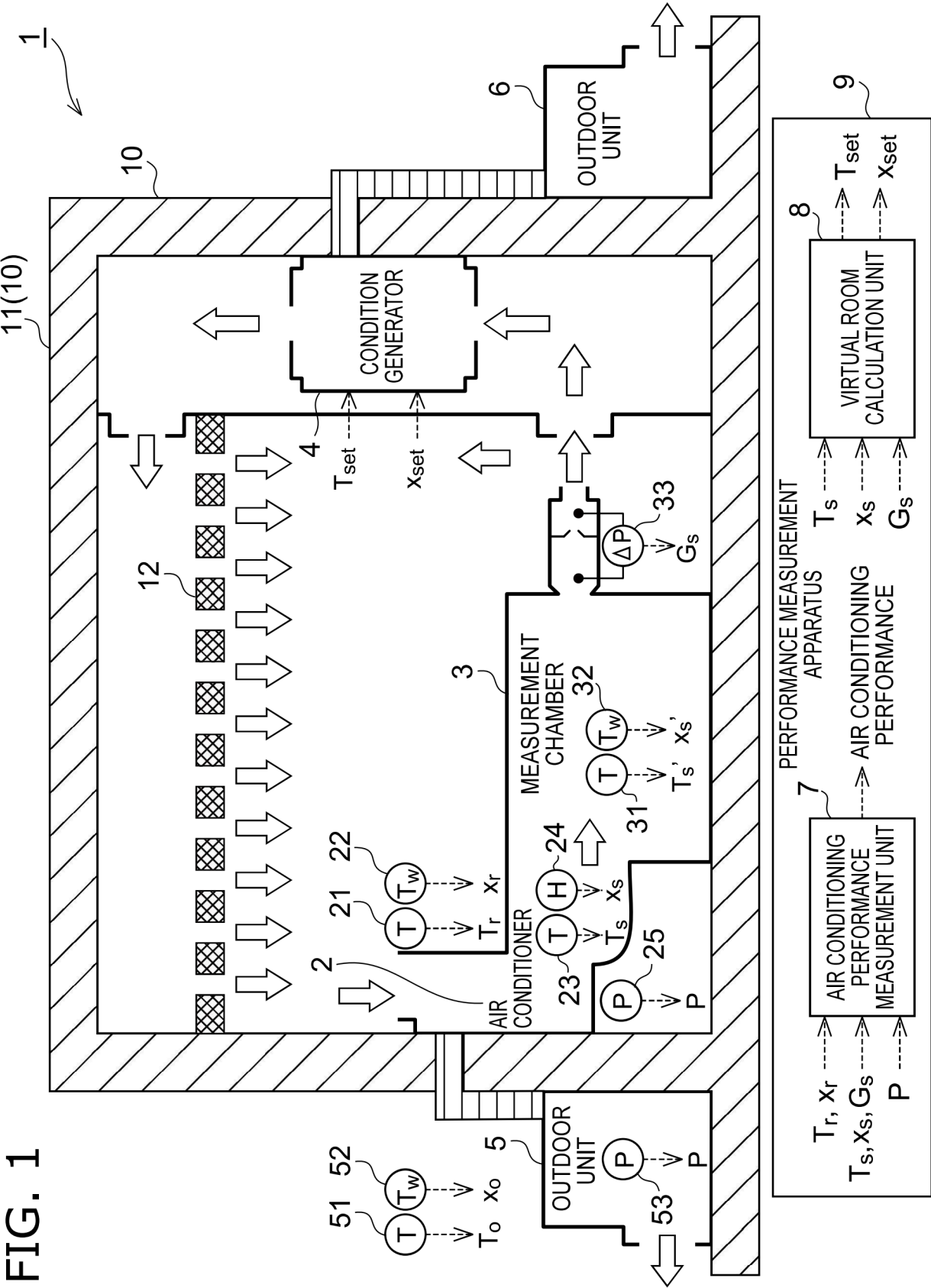


FIG. 2

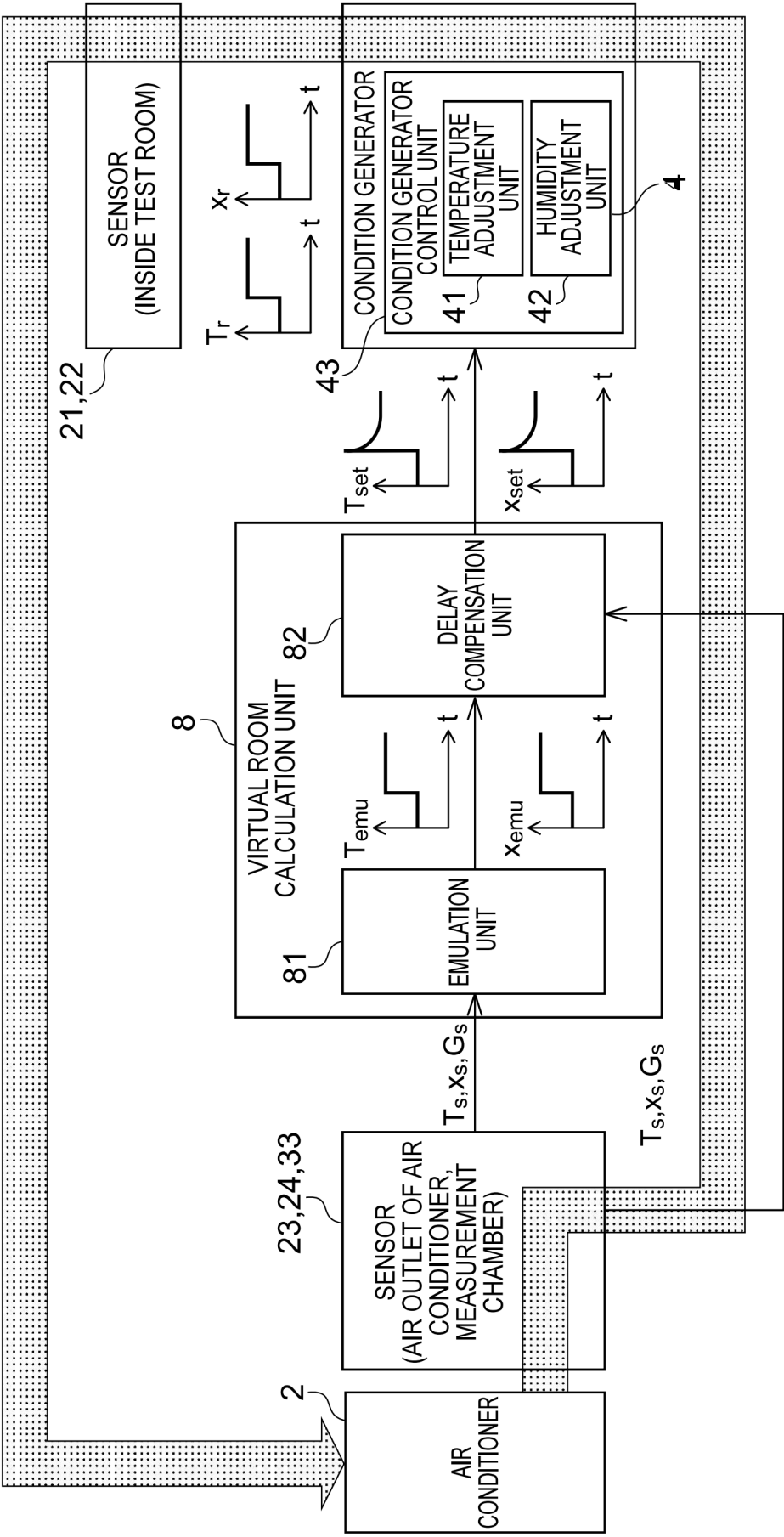


FIG. 3

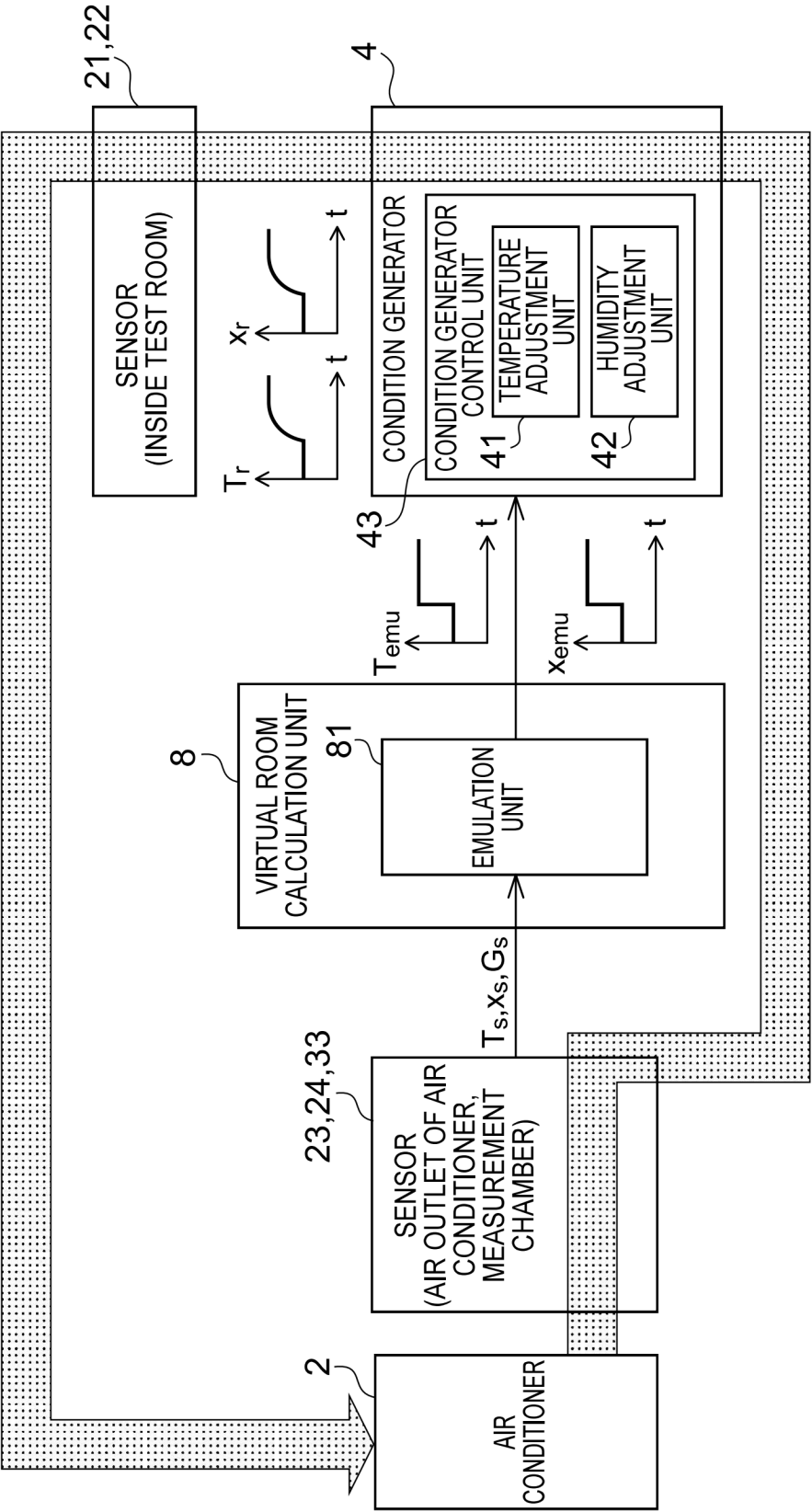
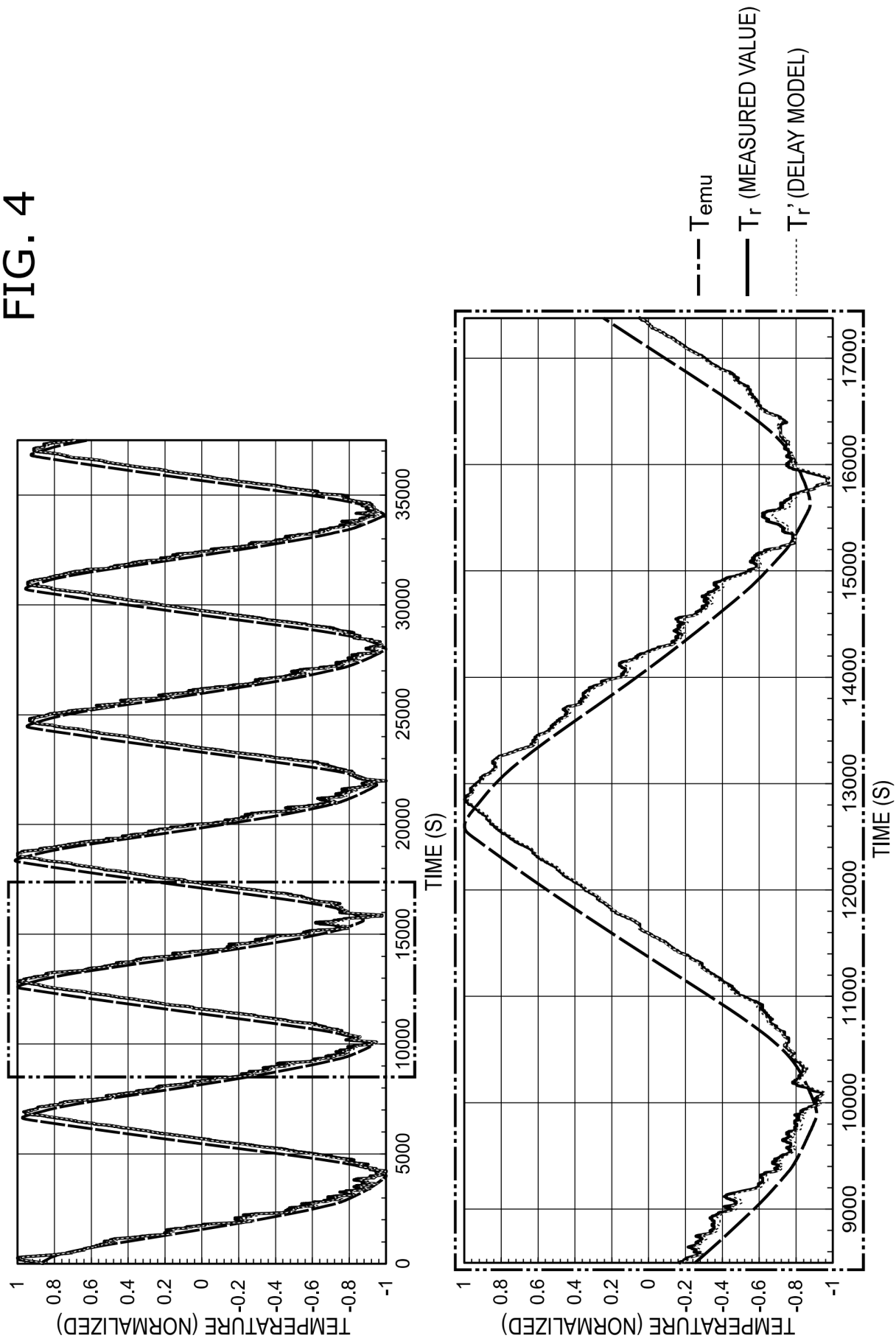


FIG. 4



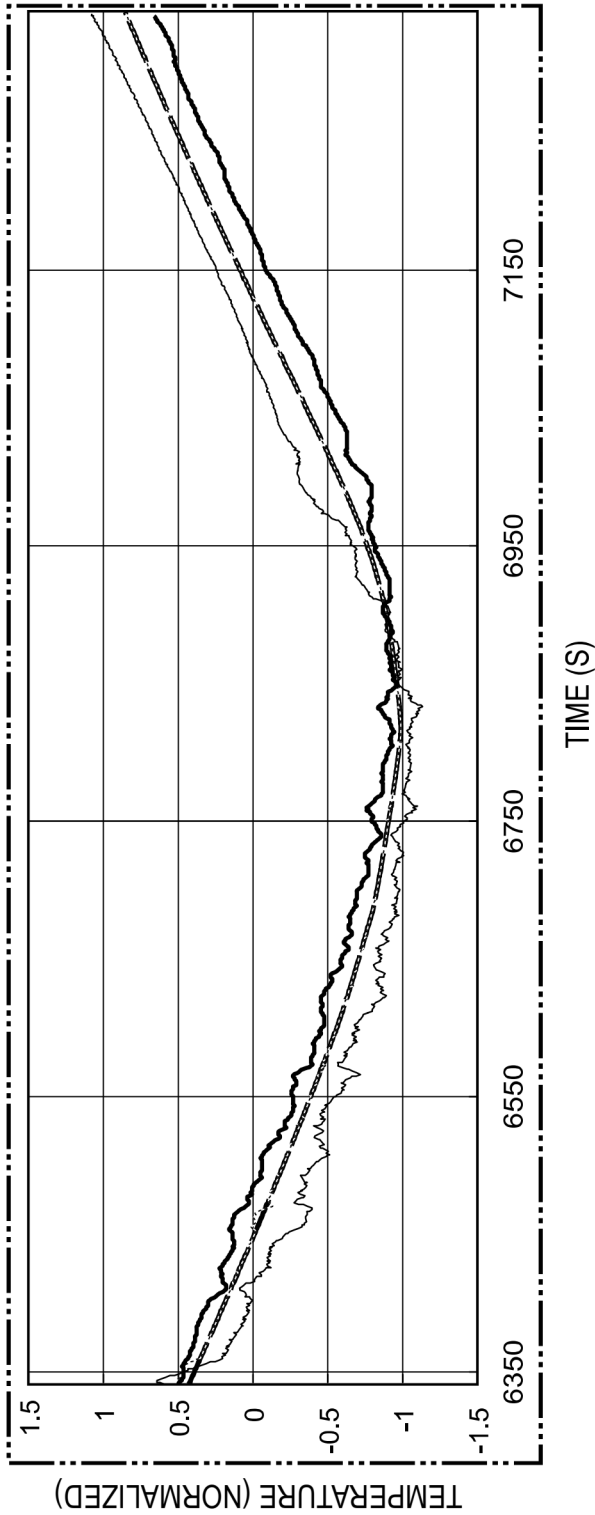
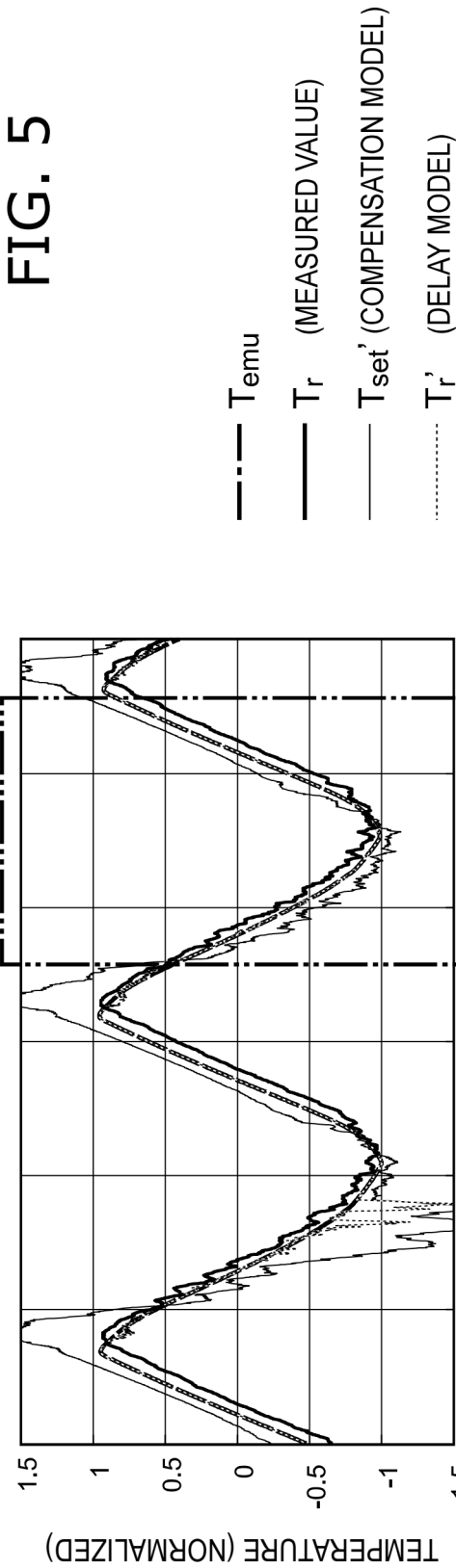


FIG. 6

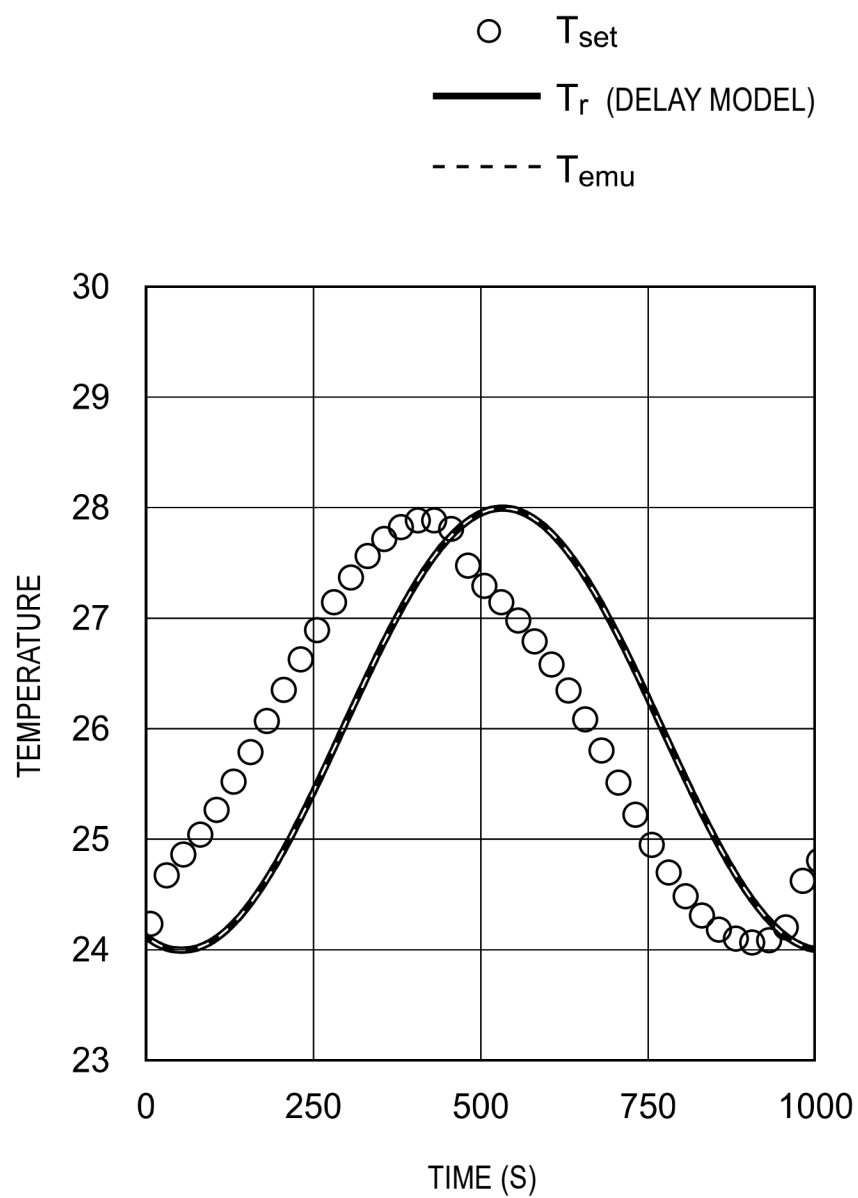


FIG. 7

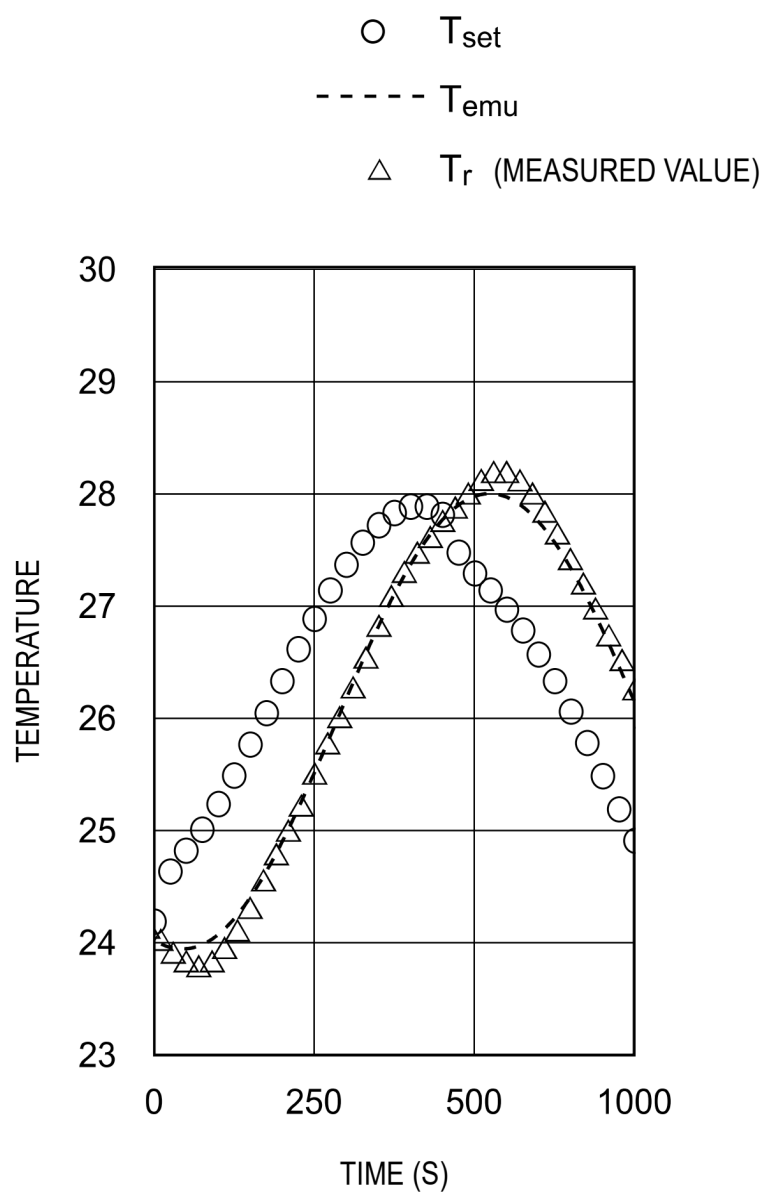
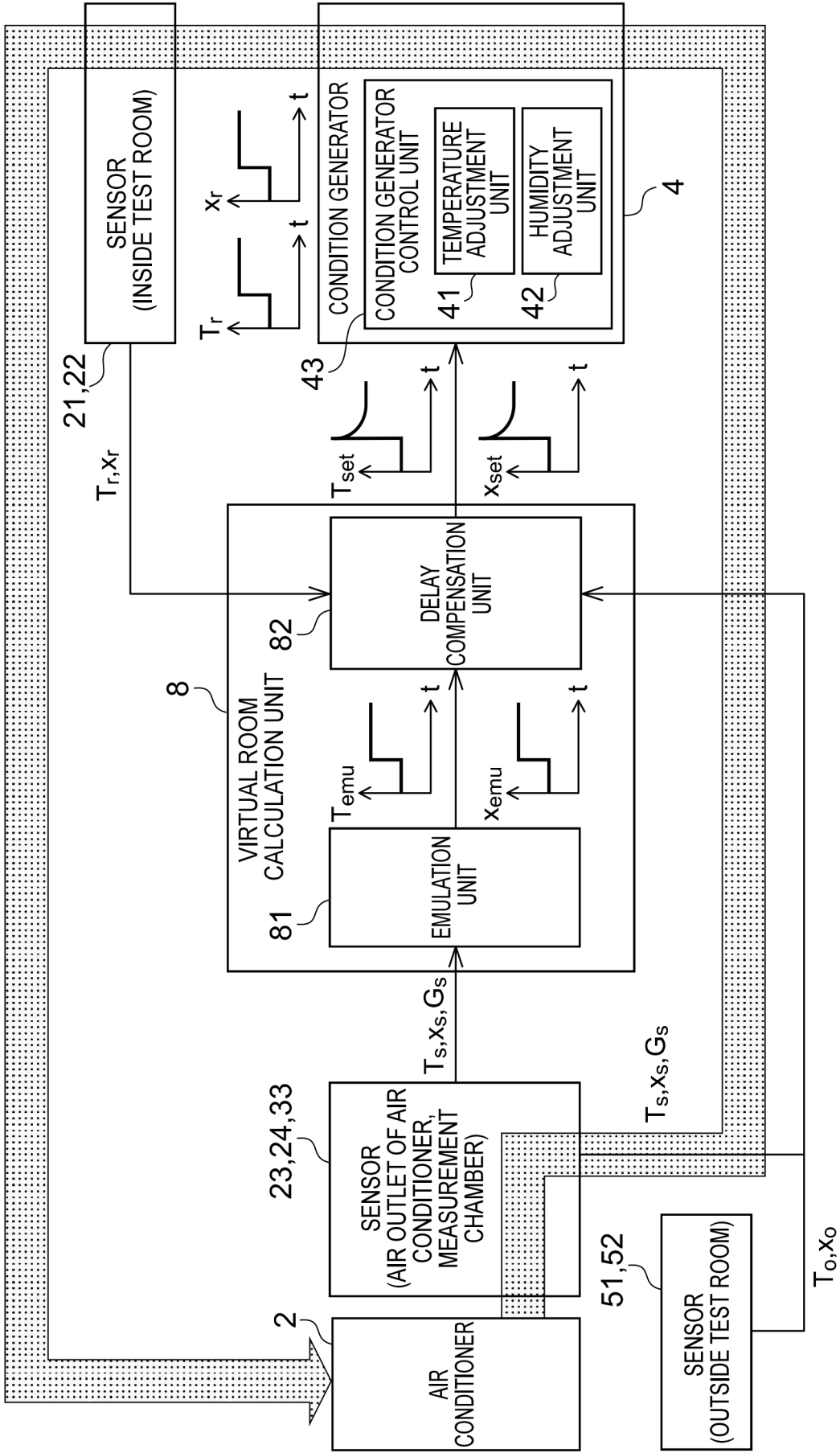


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2024/022837

A. CLASSIFICATION OF SUBJECT MATTER

G01M 99/00(2011.01)i; F24F 11/49(2018.01)i
FI: G01M99/00 Z; F24F11/49

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01M99/00; F24F11/49

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2024
Registered utility model specifications of Japan 1996-2024
Published registered utility model applications of Japan 1994-2024

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	宮岡 洋一 ほか, エミュレーター式負荷試験装置によるエアコンディショナーの動的試験, Transactions of the Japan Society of Refrigerating and Air Conditioning Engineers, 15 February 2023, vol. 40, no. 1 (2023), pp. 1-18, in particular pp. 5-14 (MIYAOKA, Yoichi et al., Emulator-type Load-based Testing Methodology for Dynamic Performance Characterization of Air Conditioners) pp. 5-14	1-9
Y	JP 11-325564 A (TAKENAKA CORPORATION) 26 November 1999 (1999-11-26) paragraph [0021]	1-9
Y	JP 2007-41947 A (OKANO ELECTRIC WIRE CO., LTD.) 15 February 2007 (2007-02-15) paragraph [0090]	1-9
A	JP 7-56604 A (LANDIS & GYR POWERS INC.) 03 March 1995 (1995-03-03) entire text, all drawings	1-9

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Date of the actual completion of the international search

07 August 2024

Date of mailing of the international search report

20 August 2024

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
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Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2024/022837

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Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	11-325564	A	26 November 1999	(Family: none)	
JP	2007-41947	A	15 February 2007	(Family: none)	
JP	7-56604	A	03 March 1995	US 6264111 B1	
----- entire text, all drawings -----					

REFERENCES CITED IN THE DESCRIPTION

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